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Design and Implementation of Socialization Assistance Device for the Deaf-Blind Community

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Abstract

Deaf-blind people face major communication issues due to a lack of appropriate technology. Our system, a braille device designed specifically for the deaf-blind, provides a solution to the problem by allowing users to feel and interpret each letter by touch in real-time, enabling smooth conversation. They can understand messages and interact meaningfully with this tactile interface, thereby overcoming the communication gap. The innovation allows deaf-blind people to participate more completely in social interactions and access information independently, improving their quality of life and promoting inclusion.

Keywords: *Assistive technology; Clean technology; Deaf-blind; Refreshable braille display; Speech recognition.*

1. Introduction

Deaf-blind people often rely on tactile methods such as braille, but not everyone knows this tactile language. Therefore, deaf-blind people often find it difficult to interact with them. Here comes the relevance of this system. By offering real-time braille translations in three modes: audio, image and text, the proposed system seeks to bridge the communication gap between deaf-blind and abled people. With an emphasis on device affordability and accessibility, the paper intends to improve participation of the deaf-blind in social, educational, and professional environments. The goal is to develop a socialization aid that will let the deaf-blind people communicate in real-time using image captioning, text-to-braille, and speech-to-text algorithms. Overall, the device seeks to increase participation, close communication gaps, encourage inclusivity, and provide a flexible communication platform for those with dual sensory impairments.

2. Literature Review

The advances in assistive technology for the deaf-blind are examined in this literature review, with particular attention paid to text-to-braille, speech-to-text, braille display devices, and image captioning techniques. It examines the limitations of current technologies and explores how machine learning and artificial intelligence can be used to improve existing technologies. Integrating touch-sensitive gloves with two-way communication is a promising wearable technology approach [1]. The HC-05 Bluetooth module and 16-bit ultra-low-power Microcontroller Unit (MCU) enable this. However, the complex design and operation may make it difficult for users to adapt to the technology. Addressing these input and complexity issues are necessary. In a communication system, vibration buttons are used to display the braille output [2]. It uses software to decode braille code and uses vibration patterns to transmit information. However, it has its drawbacks, such as difficulty in tactile feedback and a limited input format. Additionally, the message must be understood by the deaf-blind individual, making real-time communication difficult and requiring additional training or adjustments. A speaker-independent system using the HM2007 integrated circuit employs Hidden Markov Models (HMM) as its acoustic model and represents a significant breakthrough in speech recognition [3]. Particularly fascinating is its integration with solenoid actuators, which enables braille output display and provides vision-challenged individuals with an inclusive mode of communication. Despite these advantages, a drawback arises from the fact that pop-up pins have a tactile responsiveness that solenoid actuator output lacks. Because braille cannot be felt by the hand as easily, its effectiveness and user experience are limited. The device’s sole reliance on speech as an input method may limit their potential for integrating alternative methods. There are three image captioning methods: CNN-RNN, CNN-CNN, and reinforcement-learning frameworks [4]. CNN-RNN uses Recurrent Neural Network (RNN) for sequential language production and Convolutional Neural Network (CNN) for image feature extraction while reinforcement-based frameworks use reinforcement learning techniques to optimize photo captioning. The significance of image captioning approaches in computer vision and natural language processing calls for more research and comparison. The primary conversion technologies for assistive technology systems include text-to-speech (TTS), speech-to-text (STT), braille-to-text (BTT), and text-to-braille (TTB) [5]. Every technique has benefits and drawbacks of its own. However, the current state of spoken language technology is inadequate compared to human speech output. Research and development in this constantly changing field are crucial for blind and visually impaired individuals. A report on speech-to-braille language encoding for blind people [6] presents an innovative mobile communication system featuring an HC-05 Bluetooth module, an Liquid-Crystal Display (LCD) for braille output, an ATmega16 Microcontroller for processing, and a mobile app for communication. However, because the system only accepts audio as input and does not provide tactile output, it is not beneficial to users who are deaf-blind [7]. The literature review offers a comprehensive overview of technologies for sensory impairments, focusing on the blind and visually impaired. Studied approaches include touch-sensitive gloves, vibration buttons, and various conversion technologies [8]. Common limitations involve complex design, requirement of additional training, limited input formats, and real-time communication challenges. The proposed system addresses these by combining simple tactile feedback, intuitive interaction, and versatile input methods [9]. To the best of our knowledge, a system similar to the proposed system does not currently exist. The contributions of this work are as follows: It has an innovative approach for addressing the challenges faced by the deaf-blind community through a comprehensive system that includes three modes of input [10]. This system tackles the limitations of previous systems by offering real-time communication through a combination of speech recognition, image captioning, and text-to-braille mapping techniques. Unlike existing systems that may not fully cater to the needs of the deaf-blind, this proposed system focuses on empowering deaf-blind individuals by providing a versatile and interactive communication platform. Additionally, the system addresses the challenges of device ownership and cost that have limited the usability of previous systems by making a cost-efficient and compact design. The remaining sections of this paper are structured as follows: Section 3 introduces the proposed system, Section 4 covers the methodologies employed, and Section 5 delves into the system's implementation and potential challenges during development. Following this, Section 6 contains intended results and discussion about the system’s impacts, while Section 7 provides a comprehensive conclusion about the system, including insights into future developments.

3. Proposed System

In response to the evolving landscape of assistive technology, this paper proposes a novel and comprehensive system designed to address the challenges faced by deaf-blind people. The proposed system is composed of both software and hardware components. The software component consists of a mobile application that the abled person can use to initiate the conversation. The message transfer between an abled person and a deaf-blind person is handled by the software component. The hardware is an electronic braille system designed to aid the deaf-blind in perceiving the message being transmitted. It is composed of Arduino, Bluetooth module, MOLBED (Modular Low-Cost Braille Electronic Display), and other parts. A single cell of MOLBED is shown in Figure 1.

Figure 1 **MOLBED**

The key innovation of the proposed system lies in accepting three input types: text, audio, and image. Through the smartphone application, an abled person can send a text, audio, or image message. By offering this feature, this system differs greatly from other alternatives. The proposed system presents several advantages, including the facilitation of real-time communication between deaf-blind individuals and abled individuals. The electronic braille device utilized for displaying transmitted messages is refreshable, ensuring timely interaction and also generates no waste materials. The conventional method for reading braille involves printing braille characters on paper, resulting in the disposal of these papers after use, leading to significant paper wastage. The proposed system addresses this challenge by using a refreshable braille display so that the braille can be printed again and again on the same device. This advancement significantly reduces paper wastage, offering a more sustainable approach to braille reading. The mobile application offers a versatile communication experience with three modes: text, audio, and image inputs. The specially developed device for the deaf-blind is not only portable but also features a simple design for easy use. Additionally, the mobile application has a user-friendly interface, allowing individuals with sight and hearing abilities to effortlessly engage, thus significantly improving communication between deaf-blind individuals and others. The system described in this paper significantly contributes to improving social engagement within the deaf-blind community by addressing communication delays. In situations where the abled person is unable to speak, the system facilitates seamless interaction through text-based communication. Moreover, to accommodate individuals with limited English proficiency, the system incorporates image captioning techniques, allowing users to capture images that are then converted into corresponding braille. These inclusive features empower the deaf-blind to communicate effectively, irrespective of the abled person's language proficiency or ability to speak, fostering a sense of inclusivity and enhancing social engagement for the deaf-blind community.

4. Methodology

To facilitate communication and accessibility for the deaf-blind community, the proposed system incorporates multiple techniques. Figure 2 shows the process flowchart for the system.

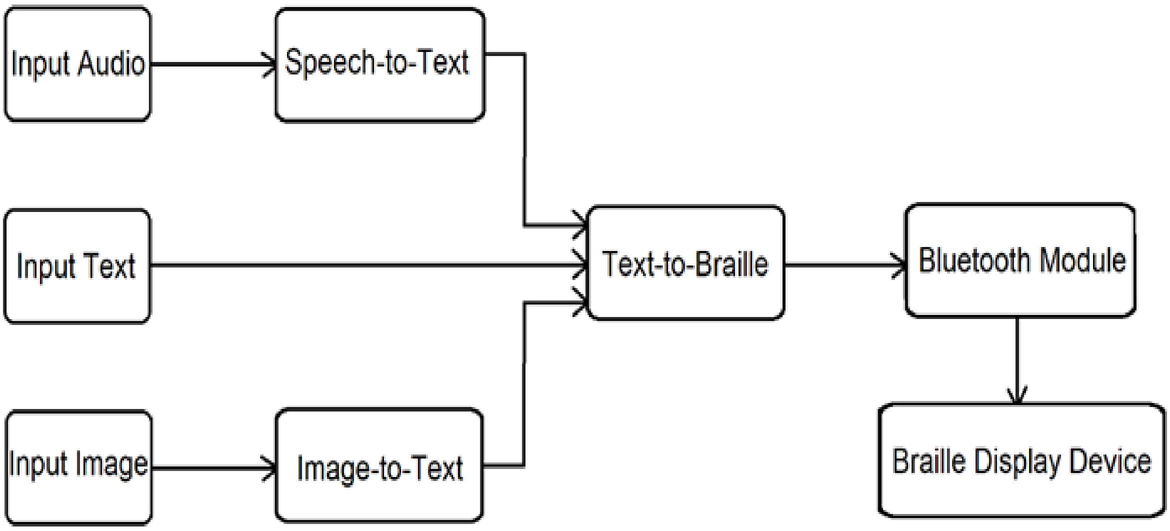


Figure 2 **Process Flowchart**

The user has three options for input: text, image, and audio. The speech and image inputs are converted to text and subsequently to braille while the text input is directly converted into braille. A Bluetooth module is used to send the converted data to a braille device, which then displays the final output. The various technologies adopted in the system are described below.

4.1.Speech Recognition

Speech recognition, also known as speech-to-text, is the ability of a machine or a program to identify words spoken aloud and convert them into readable text. This technology uses various algorithms and computation techniques, including deep neural networks and recurrent neural networks, to convert spoken language into written language. It enables the recognition and translation of spoken language into text through computational linguistics. This allows deaf-blind individuals to participate in conversations by converting their speech into text that can be displayed on the braille display. Therefore, speech recognition is a crucial aspect of this system. Here, the proposed system will be using the Speech-to-Text plugin of Flutter, which is both easy to use and provides accurate results.

4.2.Image Captioning

It contains techniques for automatically generating text descriptions of images, enabling deaf-blind individuals to understand the visual content during conversations. Techniques such as deep learning and computer vision can be used to automatically generate text descriptions of images. This technology, when integrated into the system, will enable deaf-blind users to better understand and appreciate visual content, thereby improving their overall communication experience. The system will be using deep learning-based image captioning models to achieve image-to-text conversion.

4.3.Text-to-Braille Mappings

Text-to-braille mappings involve techniques for converting text input into braille characters, allowing deaf-blind individuals to read and write text on a braille display. Techniques such as character recognition and segmentation algorithms can be employed to convert text input into braille characters. This technology will enable deaf-blind users to navigate and interact with text-based information more efficiently, thereby improving their overall communication and accessibility experience. Here, in this system, a simple mapping is implemented using a Python dictionary for the text-to-braille conversion

4.4.Braille Device

The Arduino, Bluetooth module, and MOLBED are the hardware components of the braille device. These elements are responsible for the hardware's core operations. The system employs an Arduino to oversee and manage MOLBED’s functions. Transmission of braille characters from the mobile application to the hardware display is facilitated by a Bluetooth module. The MOLBED features pins for displaying messages from a mobile application. Each braille character on the prototype is represented by a set of six pins, crafted with various components, including 3D-printed parts, magnets, coil, etc.

5. Implementation and Challenges

The implementation of the proposed system consists of three phases: software, hardware, and integration. The front-end application that receives user input and sends the braille to the hardware device is implemented during the software phase. It consists of different pages that each of the three input types requires. The entire application is written in Dart, utilizing the Flutter framework. The application's home page consists of three options: 'Audio', 'Image', and 'Text'. Each of the options leads to the corresponding page that takes in the input and sends it to the backend for processing. Python is used in the backend implementation to take advantage of its extensive machine learning libraries for image captioning, speech-to-text, and other uses. The backend includes text-to-braille conversion methods, image captioning techniques based on deep learning models, speech-to-text, and finally braille-binary mappings. The braille-binary mapping is achieved using dictionaries. In the end, the backend will transmit the binary to the hardware device over Bluetooth. Therefore, the Bluetooth module acts as the middleware for the transmission. The actual braille display device is implemented in the hardware phase while in the integration phase, the software and the hardware components are combined to produce the final system. The hardware device receives the braille input from the front-end application through the Bluetooth module and uses the MOLBED system to display it. During the development of this system, several challenges may arise. These challenges can be categorized into different aspects:

5.1.Technical Challenges

The system relies on advanced technologies such as speech recognition, image captioning, and text-to-braille mappings. Developing and integrating these technologies into the system may pose challenges, as they must be robust, user-friendly, and accessible for individuals with vision and hearing impairments. Also, these conversions need to work in real time and be fast and accurate.

5.2.Hardware and Software Integration

The system requires seamless integration of hardware and software components to work properly. Ensuring compatibility and smooth communication between these components may present challenges, as different technologies and platforms need to work together effectively.

5.3.Accessibility and Affordability

The proposed system seeks to make communication more affordable and accessible for individuals with vision and hearing impairments. Ensuring that the system is affordable and accessible to a wide range of users may pose challenges, as it needs to consider factors such as device ownership, cost of assistive devices, and user preferences. In conclusion, the development phase will be facing various challenges, and addressing these challenges will be crucial for the successful implementation and adoption of the system by individuals with vision and hearing impairments.

6. Results and Discussion

The proposed system will yield significant results in the field of assistive technology, particularly for the deaf-blind community. To improve social inclusion, communication, and accessibility for the deaf-blind community, the system's outcomes cover both its technical and social effects. To begin with, the system features a mobile application that is easy to use and fully functional, enabling real-time communication and information access. Three input options are displayed on the application's home page: text, audio, and image, as Figure 3 illustrates. All these options lead to the relevant pages.

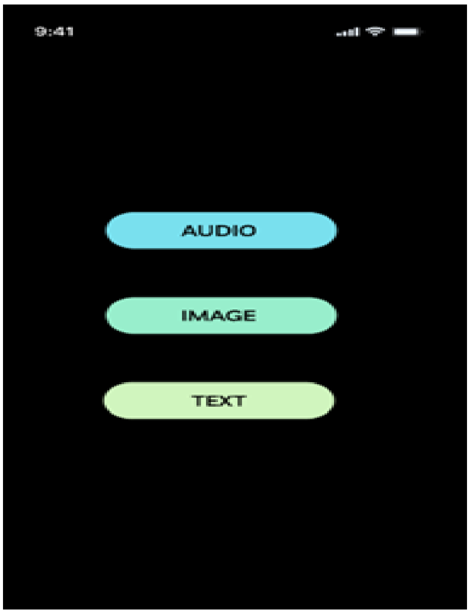
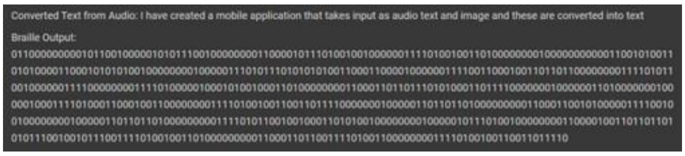


Figure 3 **Home Page of the Application**

Figure 4 illustrates the resulting braille output of an audio input, represented in binary as 0's and 1's. The received input, in the form of both audio and images, undergoes a two-step conversion process to get the final braille output. For textual input, a direct conversion to braille is performed.


Converted Text from Audio: I have created a mobile application that takes input as audio text and image and these are converted into text

Braille Output:

Figure 4 **Output of Speech-to-Text and Text-to-Binary Mappings**

The mobile application for the system is compatible with widely available technologies, such as Android platforms, and offers a versatile communication experience for both able and deaf-blind users. Figure 5 depicts the model of a hardware device that displays braille characters in real-time and facilitates smooth communication for people with vision and hearing impairments and Figure 6 illustrates the prototype for a single cell of the device. A tactile braille display that efficiently converts several input modalities, such as text, audio, and image, into braille output is the intended outcome. This hardware component is user-friendly, portable, and cost-effective, addressing the unique communication needs of the target demographic.

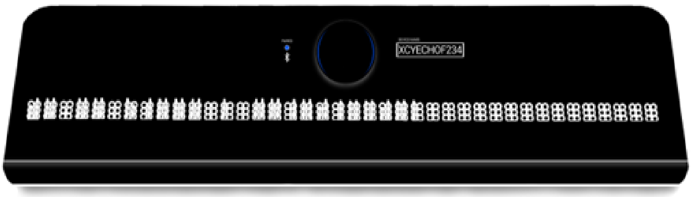


Figure 5 Braille Display Device

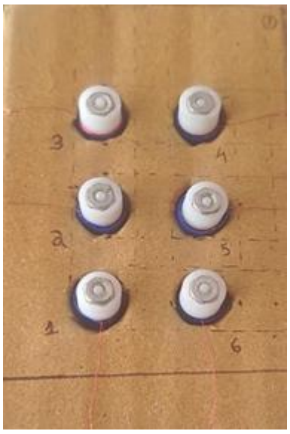


Figure 6 Prototype for A Single Cell of the Device

The proposed system aims to foster greater inclusivity and participation for individuals with dual sensory impairments, encouraging them to engage in social, educational, and professional environments. By enabling real-time communication and information access, the system seeks to empower deaf-blind individuals, thereby enhancing their overall quality of life. The paper aims to address the accessibility and affordability challenges faced by individuals with vision and hearing impairments. The final outcome is a user-friendly and cost-effective communication system that caters to the diverse needs of the deaf-blind community that promotes greater independence and social engagement. The proposed system is expected to have a positive impact on the lives of deaf-blind individuals by providing them with a means to participate more fully in society.

Conclusion and Future Scope

In conclusion, this paper proposes a novel solution to address the social isolation experienced by deaf-blind individuals. The proposed system uses tactile feedback to enable communication and social interaction, allowing deaf-blind individuals to connect with others and participate in social activities. The system has the potential to improve the quality of life for deaf-blind individuals and promote their inclusion in society. The future vision for the system is to enhance communication in the deaf-blind community by enabling two-way communication and initiating dynamic conversations. Other future developments include reinforcing hardware with a robust battery backup, ensuring sustained functionality. Additionally, the innovative software of the system can be implemented on wearable devices like smartwatches, aiming for broader accessibility and seamless integration into users' daily lives. This future scope aims for continuous improvement, adaptability, and breaking down communication barriers for the deaf-blind.

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